COMMITTEE ON RADIOLOGICAL HAZARDS TO PATIENTS

FINAL REPORT OF THE COMMITTEE

PART I. INTRODUCTION

1. We were appointed by the Secretary of State for Scotland and the Minister of Health at the end of 1956. Our terms of reference were "to review the present practice in diagnostic radiology and the use of radiotherapy in non-malignant conditions having regard to the report of the Committee on the Hazards to Man of Nuclear and Allied Radiations (1) and to make recommendations".

2. We published an Interim Report in May 1959 dealing with Mass Miniature Radiography and a Second Report in 1960 in which the whole field of medical radiology including the radiotherapy of malignant disease, was surveyed and an estimate made of the genetic dose to the population from this source of radiation. Early in our deliberations, we had decided that the effects of radiation on the individual (somatic effects) must also be included in any consideration of radiological hazards to patients and this report now deals with the estimation of the dose related to somatic effects.

3. The main survey by which the genetic dose was determined was so designed that the statistical and physical data necessary for calculating a dose related to particular somatic effects could also be obtained. Before these data could be used to calculate a somatic dose, however, it was necessary to undertake a large number of laboratory measurements on a model of the human body. The subsequent calculation of the somatic dose entailed the development and operation of a complex computer programme. We believe that the results given in this report, which are based on the 1957/58 surveys and the subsequent laboratory work, represent the most comprehensive investigations yet made into the problem of estimating the dose relevant to any possible somatic hazards from the medical uses of ionising radiation.

4. The somatic effects of radiation are biological changes in cells and in tissues of the individual which concern only the irradiated person and are not transmitted to subsequent generations. These effects include such overt manifestations as reddening of the skin and loss of hair, cataract formation, ulceration following a large dose of X-rays, and the skin cancers that developed on the heavily irradiated hands of the early X-ray pioneers. We should note that damage of the extent just described is associated with radiation doses which are large compared with those generally received today in the course of diagnostic X-ray examinations. Somatic effects also include damage caused by irradiation of the foetus, which may follow exposure to lower doses, as well as damage to the blood-forming organs, chiefly the bone marrow. Radiation damage to the

marrow can result in a diminution of the number of circulating white cells, loss of the capacity to produce red cells and malignant changes of the bone marrow itself.

5. In view of this variety of possible effects and the fact that many different tissues are irradiated in the course of radiological procedures, it is clearly not practicable to propose any single dose parameter which would have equal relevance to the irradiation of all the different body tissues. The most we can do is to attempt to derive some particular tissue dose which can be regarded as relevant to some particular somatic effect. Thus it is known that bone marrow is one of the tissues especially susceptible to damage by radiation. Moreover, leukaemia, a malignant form of bone-marrow disease, appears to be a sensitive manifestation of radiation damage to bone marrow. It is also the manifestation about which most is already known in relation to radiation dosage (2). On these grounds we decided that the active bone marrow was the most important tissue to consider and that the dose to bone marrow was the most informative parameter to be derived from our measurements.

6. The present knowledge of the relationship between leukaemia incidence and radiation dose is not sufficient, however, to indicate whether the physical parameter should be the mean dose to the marrow as a whole, or the maximum dose received by any part of the marrow or some other parameter such as a function involving higher powers of the dose. On the other hand, at low dose levels, such as those associated with diagnostic radiology, there are theoretical and experimental grounds for believing that the mean dose averaged over all cells at risk is the one most likely to be relevant to such a radiobiological effect (3). At the higher dose levels, there is direct evidence of a relationship between mean marrow dose and the observed increase in the incidence of leukaemia (1) (3). We have therefore adopted the criterion that the irradiation of any part or the whole of the bone marrow should be expressed as a mean dose averaged over the whole active marrow. The mathematical definition of this "mean marrow dose" is given in Part II of this report.

7. At low dose levels any increase in the risk of developing a given somatic effect will be detected only by making statistical studies of the incidence of the effect in large numbers of the population. In estimating the possible effects of diagnostic radiology, account should be taken of the fact that some 18 million X-ray examinations are performed annually and that in consequence, a person may be regarded as having, on average, an X-ray examination once in every three to four years. Further, the average person may be regarded as accumulating doses from diagnostic X-ray examinations throughout life. Therefore, in order to state the dose relevant to an increase in the incidence of leukaemia in the whole population, we have averaged the dose received by those medically irradiated over the whole population and have expressed it as a mean marrow dose per head of population per year. We have also stated the dose which may be received on average in a single examination and also on the above basis, the dose a person may receive on average from radiological examinations in the course of a lifetime. Clearly there will be very considerable variations about these averages in individual cases; taken as a whole, however, they can be used to give a measure of the average risks involved.

8. The considerations given in the preceding paragraph are less relevant when only a small fraction of the population is irradiated annually. The annual number of patients treated with X-rays for non-malignant disease amounted in 1957/58 approximately to 60,000 and almost the same number were treated by radiotherapy for malignant diseases. For these numbers, totalling in each case only about one thousandth of the population, different modes of presentation are required. In the radiotherapy of non-malignant diseases, the doses are expressed as the mean marrow dose per course of treatment received by the patient. For purposes of comparison with other sources of population exposure to radiation, the product of the mean marrow dose per treatment course and the number of patients treated per year can be used to give a total radiation exposure in terms of "patient-rads"*. This method of expressing the dose is also used in this report to compare the magnitude of the dose contribution from different types of treatment.

9. The radiation doses to bone marrow generally received in the radiotherapy of malignant disease, however, greatly exceed bone marrow doses associated with diagnostic procedures and are large compared with doses given in the treatment of non-malignant conditions. These high doses are justified in view of the gravity of the conditions that are treated. They are set out in Part IV for their scientific value stated simply as the mean marrow doses associated with typical therapeutic procedures.

10. The results of our investigations show that in the years of the survey, the mean marrow dose per head of population per year contributed by diagnostic radiology was 32.4 mrads the average dose to the bone marrow per examination was about 100 mrads and on this basis, an average life-time dose would be about 2 rads.

11. Our measurements showed that the total annual radiation exposure from the radiotherapy of non-malignant disease amounted to 617,000 patient-rads or an average marrow dose of 10 rads per person irradiated. In addition, an exposure of 95,000 patient-rads was received from the therapeutic use of radioisotopes. These results all refer to the years of the surveys, 1957/58, since when some increases have occurred in the medical use of radioisotopes and there have been some downward trends in the use of radiation for the treatment of non-malignant conditions. The magnitude of these changes does not suggest that any major revision of our estimates is at present necessary.

12. We consider that these new findings on the levels of dose relating to somatic effects support the conclusions and recommendations given in our Second Report. The mean annual dose per person from diagnostic radiology is not such that there is any necessity for major restrictions in radiological practice or that the number and type of examinations should be dictated by other than the clinical needs of the patient. Nevertheless, we wish to emphasize the importance of following the recommendations of our Second Report, the implementation of which will reduce the dose to the bone marrow as well as

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* Throughout this Report we shall refer to radiation doses in terms of the unit of absorbed dose, the rad. The absorbed dose is the energy imparted by ionising radiation to unit mass of matter; 1 rad is equal to 100 erg per gram of matter, i.e. per gram of tissue irradiated.

that to the gonads. In particular, we would stress the recommendations regarding the restriction of the size of the X-ray beam to the minimum required for any given examination and the limitation of X-ray examinations which involve irradiation of the foetus. For the sake of completeness, our previous recommendations are reiterated at the end of this report.

References: (1) Medical Research Council 1956. The Hazards to Man of Nuclear and Allied Radiations H.M.S.O.

(2) Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (1964) Suppl. 14 (A/5814).

(3) Report of the Radiobiological Effectiveness Committee to the International Commissions on Radiological Protection and on Radiological Units and Measurements. Health Physics (Pergamon Press) 1963, *9*, 357/386.

PART II.

DETERMINATION OF THE MEAN BONE MARROW DOSE

National Surveys

13. By means of surveys carried out during 1957 and 1958, we estimated the extent of medical and dental radiology over the whole of Great Britain and assessed the radiation dosages received by patients. These surveys were described in detail in the First and Second Reports* and only a summary of them and of the data available is given here.

14. During one week in 1957 a survey was made of the numbers and types of X-ray examinations carried out, of the number of films used and of the apparatus available in all National Health Service hospitals and chest clinics, in dental surgeries and in a few other institutions in Great Britain. A second week's survey at a different time of year was made on a representative quarter of the National Health Service hospitals and chest clinics. From these surveys it was estimated that 13·0 million X-ray examinations were carried out in 1957 in National Health Service hospitals (II, 17–20).

15. Physical measurements of the radiation dose received by patients from diagnostic procedures were made in 1958 in a representative sample of 130 hospitals and chest clinics. By these means radiological practice was surveyed in hospitals of every type and under widely differing standards of technique. The hospital physicists who undertook these measurements in all the hospital regions thus supplied details of the dosage received by patients during 5,414 examinations, involving 13,800 individual measurements. (II, 21–27).

16. Radiation doses received during Mass Miniature Radiography of the chest were surveyed in 1958. During 1957 in England, Scotland and Wales these examinations numbered 4,770,927 (I, 12–26; II, 36–40).

17. During 1958 the gonad dose from over 10,000 X-ray exposures was measured in 152 dental surgeries and hospital dental departments. It was estimated that 2 million dental examinations were made annually, each consisting on the average of two exposures (II, 41–45).

18. The numbers and types of disease treated by radiotherapy were obtained from the National Health Service hospitals and private dermatologists for a three month period during 1957. 13,950 cases of non-malignant disease were reported from hospitals and 1,015 from private practice and it was estimated that these figures represented 90% of the treatments carried out in hospitals and one third of these in private practice. During the same 3 months patients with malignant disease treated by radiotherapy numbered 14,620 (II, 46–48, 51)

19. Details of 2,262 treatments of non-malignant disease were collected from hospitals making the above return (in proportion to the work carried out) and

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* Reference to paragraphs and tables in these reports are included in the text of this report e.g. Second Report, Paragraph 160 will be indicated by (II, 160).

from these radiation histories gonad dose and bone marrow doses were deduced. With malignant disease standard methods of treatment were assumed (II, 49, 52).

20. The numbers of patients investigated or treated by unsealed radioactive isotopes were obtained during a three month period in 1957 together with the amounts of different isotopes used. In total 6,135 patients were investigated and 1,307 patients were treated (II, 55–57).

General plan of bone marrow dose determination

21. For each patient in the sample surveys there was information on the skin dose received at a certain site on the body, the area irradiated by the direct beam and the physical specifications of the radiation used. From a knowledge of the distribution of the active bone marrow in the body the sites and proportion of the total active marrow irradiated by the direct beam could be deduced. To relate the dose received at a bone marrow site to that at the skin under a defined radiation condition, numerous measurements were made in bone marrow cavities in a specially constructed model. The dose to the bone marrow during the examination or treatment of a particular site of the body can be calculated from these three factors, viz: the skin dose, the elements of marrow irradiated and the dose received by these elements of marrow per unit skin dose. This dose to a limited site has been expressed as the mean dose to the whole of the active bone marrow. When a large proportion of the population is subjected annually to a particular radiation, as is the case with general diagnostic radiology, it is considered that the mean marrow doses received by the irradiated individuals may be averaged over the whole population to give a mean annual marrow dose per person of the population*.

Distribution of Bone Marrow

22. Published data on the distribution of bone marrow are very limited and a distribution (4) for an adult aged 40 had to be deducted by combining the figures published by Mechanik (5) on the whole bone marrow with those given by Custer (6) on the variation with age of the active marrow in certain bones. This distribution is set out in Table I below.

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* The mean narrow dose D_M averaged over the total active marrow M from a particular examination is defined as the summation, for each element of marrow m, of the product of the fraction of the active marrow exposed, the fraction of the dose to the skin reaching the element of marrow f_s and the actual skin dose D_s:—

$$D_M = \sum \frac{m}{M} \cdot f_s \, D_s$$

If out of a population N the number of persons exposed to a particular examination is N_x then the mean marrow dose per person in the population $\bar{D}_M$ will be the summation over all such groups.

$$\bar{D}_M = \sum \frac{N_x}{N} \, D_M$$

TABLE I

Distribution of Active Marrow in the Adult

Site	Percentage of total Active Marrow
Head	13·1
Upper Limb girdle	8·3
Sternum	2·3
Ribs	7·9
Cervical vertebrae	3·4
Thoracic vertebrae	14·1
Lumbar vertebrae	10·9
Sacrum	13·9
Lower limb girdle	26·1
	100·0

Measurements on the Model

23. Dose measurements were made with a very small ionisation chamber placed at twelve bone marrow sites in the specially constructed model used in the genetic dose survey (II,27). These sites were: the pituitary, as representative of the head, the 5th cervical, 3rd and 8th dorsal and 2nd lumbar vertebrae, 2nd sacral segment, lateral aspect of the pelvis, head of humerus, centre of the femur shaft, lateral aspect of the 6th rib and in front and behind the sternum. The measurements were designed to relate the dose at any given marrow site to that recorded simultaneously by a chamber on the skin at the centre of the X-ray field. For each site these doses have been measured for 7 radiation qualities from 1 mm Al. H.V.L. to 2·0 mm Cu H.V.L., for focal skin distances, 20, 40, 60 and 80 cm F.S.D. and for field areas, 25, 40, 100, 400 and 900 sq. cm and for the three directions of the incident beam i.e. anterior, posterior and lateral projections. These measurements then provide data on the exposure of the marrow within the selected bone per unit exposure to the skin.

24. In converting this exposure of the marrow to the absorbed dose in rads, the emission of photoelectrons from the mineral bone in the trabeculae must be taken into account. This emission increases the absorbed dose to the bone marrow in the trabecular spaces. The sizes of these spaces in the spine, femur, rib and iliac crest have been measured by Jacobs and Spiers (7), and combining their figures with calculations of the mean dose to cylindrical cavities, (Charlton and Cormack (8)) provides factors for converting exposure to absorbed dose. From the results obtained for these four bone sites appropriate factors were assigned to each marrow site in the body.

25. The measurements and subsequent computer programme took account only of the fraction of marrow irradiated in the direct beam of area equal to that at the skin surface. Measurements were therefore undertaken to assess the increase in marrow dose from radiation received outside this direct beam and these gave an average increase of 22%. A correction of this amount has been included, where necessary, in statements of dose*.

Method of calculation in the computer

26. The mean marrow dose from X-ray examinations and treatments was calculated with the aid of a computer. For this purpose the bodily distribution of active bone marrow given in Table I was subdivided into elements of a grid superimposed over the body in both anterior-posterior and lateral projections. The size of each grid element was 5 cm along the body axis and 3 cm across the body. (In children the element was reduced to 3 cm × 2 cm). Some elements contained up to six separate sites of marrow. From the given centering point and the dimensions of the X-ray field on the skin the computer could determine the number of grid elements to include in the calculation. For each element so selected the marrow dose contribution arising from the particular exposure conditions was calculated for each site of marrow within the element using the data obtained from the physical measurements on the model. The individual element sums were then totalled to provide the marrow dose in rads to the active marrow exposed from the particular examination or treatment. The mean dose to the whole of the active marrow was then derived.

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* The details of these measurements will be included in a publication entitled " Scientific data on the estimation of the genetic dose and bone marrow dose from X-ray examinations and treatments ".

(4) Ellis, R. E., 1961, Phys. Med. Biol., *5*, 255.
(5) Mechanik, N., 1926, Z ges anat., *79*, 58.
(6) Custer, R. P., 1949, Atlas of Blood and Bone Marrow (New York, W. B. Saunders).
(7) Jacobs, N., and Spiers, F. W., 1963, in "Radiation Effects in Physics, Chemistry and Biology", proceedings of Second International Congress of Radiation Research, 462.
(8) Charlton, D. E., and Cormack, D. V., 1962, Rad. Res., *17*, 34.

PART III. MEAN BONE MARROW DOSE IN DIAGNOSTIC RADIOLOGY

27. The results of the investigations of the bone marrow doses arising in general diagnostic radiology, mass miniature radiography of the chest, dental radiography and in the diagnostic use of radioactive isotopes are set out and considered in this part of the Report.

General diagnostic radiology

28. The averages of the mean bone marrow doses per examination are given in Table II for groups of X-ray examinations which together contribute more than 75 per cent of the total population mean marrow dose (See Table AI at the end of the report for the detailed results for all examinations). It will be seen that the examinations involving fluoroscopy tend to give the highest dose.

TABLE II

General Diagnostic Radiology: *National Survey*, 1957/58

Mean Marrow Dose per X-ray Examination in Millirads

	Male mrads		Female mrads
*Barium meal	505		799
*Barium enema	528		1,060
Whole Chest	12		13
Lumbar Spine	270		270
Intravenous Pyelography ...	584		452
Abdomen	123		129
Abdomen obstetric ...		Foetus 500	206
Pelvimetry		Foetus 1120	283

29. An analysis of the effects of techniques has been undertaken for ten examinations and is shown in Appendix B. This reveals the variations in bone marrow dose for essentially the same type of examination together with the correlation between the mean marrow dose and with each of four exposure parameters, i.e. the central skin dose, the radiation quality, the total field area and the fluoroscopic exposure time.

30. The computation assumed that there was no active bone marrow in the arms and legs except for the head of the humerus and femur. In children all bones contain some active marrow and hence some error has been introduced into these calculations, though this is partially compensated for in that in the calculation the percentage of active marrow in the trunks of children was correspondingly increased.

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* The differences between the male and female doses in barium meal and barium enema examinations arise mainly from the longer screening times used in some of the female examinations—see histograms in Appendix B. It should be noted that the number of barium enema examinations measured is small (Table A1).

31. The dose to the foetus during examinations of the obstetric abdomen and pelvimetry has been assessed from the data given by Bewley, Laws and Myddleton (9) and by Clayton, Farmer and Warrick (10). The average dose to the whole foetus was assumed to be the best estimate of the mean bone marrow dose. The mean dose to the foetus during both these examinations is high since a large proportion of the foetus is irradiated.

32. The mean bone marrow doses per person of the population calculated from the survey data are given in Table III below for the examination groups of Table I and for all other examinations grouped together (see Table A II at the end of the report for the detailed results). By far the most important is the barium meal examination which contributes 27% of the total while the other fluoroscopic examinations, barium swallow and barium enema contribute a further 15%. Orthopaedic examinations of the spine together with those examinations which involve the trunk such as the intravenous pyelograms and examinations of the abdomen each contribute about 10%. Each examination of the chest contributes only a small mean bone marrow dose but it is important since this examination is made so frequently (II, 29). Not including Mass Miniature Examinations, it contributes about 8% of the total.

TABLE III

General Diagnostic Radiology: National Survey, 1957/58

Annual Mean Marrow Dose in Millirads per person

Examination	CONTRIBUTION		Total	Percentage
	Males	Females		
Barium meal	2·39	3·58	5·97	26·6
Barium swallow, enema	1·32	2·04	3·36	15·0
Whole Chest	1·01	0·83	1·84	8·2
Whole Spine	2·05	0·98	3·03	13·5
Intravenous Pyelography	1·37	0·92	2·29	10·2
Abdomen	0·38	0·39	0·77	3·4
Abdomen Obstetric	— 0·40+	0·33 0·40+	1·13	5·0
Pelvimetry	— 0·21+	0·11 0·21+	0·53	2·3
All other examinations	1·92	1·64	3·56	15·8
	11·1	11·4	22·5	100·0

+ Foetal contribution.

33. In total the annual mean marrow dose to the population from general diagnostic radiology in National Health Service hospitals amounts to 22·5 mrads to which an estimated 1·9 mrads has to be added for examinations performed outside the National Health Service (estimated at 1·1 million per year (II, Table 17)). The total annual mean bone marrow dose from general diagnostic radiology is therefore 24·4 mrads.

Mass Miniature Radiography of the Chest

34. The skin doses received by 347 patients during examinations in 13 centres were used to calculate the mean marrow dose of 61 mrads for males and 101

mrads for females (II, Table 20). These doses are higher than those found in the general diagnostic survey in hospitals where a large full size radiograph requiring a smaller exposure is usually taken.

35. During 1957 there were 95·4 mass miniature examinations per thousand of the population and the resulting annual population dose is 7·8 mrads per person.

Dental Radiography

36. In the calculation of the bone marrow dose from dental radiography it was assumed that an average dental examination consisted of two exposures each delivering a skin dose of 1·5 roentgens to an area 5 cm × 6 cm. The mean bone marrow dose per examination was thus calculated to be 1·8 mrads.

37. With 2 million dental X-ray examinations per year, the annual population dose is 0·1 mrad per person.

Diagnostic Use of Radioactive Isotopes

38. The bone marrow dose to an individual from one microcurie of administered radioactive isotope has been estimated for Iodine-131 and Phosphorus 32 as 1·7 mrads and 12 mrads respectively.

39. From the data provided during the three month survey (II, Table 28) of the diagnostic use of radioactive isotopes the annual population dose is estimated to be 0·1 mrad per person. This consists of approximately equal contributions from Iodine-131 and Phosphorus-32.

Summation of the population bone marrow dose from diagnostic radiology

40. These results are brought together in Table IV.

TABLE IV

General Diagnostic Radiology: National Survey 1957/58

Annual Population Mean Marrow Dose in Millirads per person

General diagnostic radiology: N.H.S. hospitals	22·5
Other hospitals ...	1·9
Mass Miniature Radiography	7·8
Dental radiography	0·1
Diagnostic use of radioactive isotopes	0·1
Total	32·4

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(9) Bewley, D. K., Laws, J. W. and Myddleton, C. J. 1957, Brit. J. Radiol., *30*, 354, 286.

(10) Clayton, C. G., Farmer, F. T., and Warrick, C. K., 1957, Brit. J. Radiol., *30*, 354, 291.

PART IV. MEAN BONE MARROW DOSE IN RADIOTHERAPY

(a) Treatment of Non-malignant disease

41. The present estimation of the bone marrow dose derived from the treatment of non-malignant disease is based upon particulars of 2,262 patients (II, Table 22). Of these, 1,017 had received treatment to sites on the trunk and head and 1,245 to sites on the arms and legs and for the latter it has been assumed that no active marrow was exposed except in the heads of the humerus and the femur, while for the former the dose per treatment course was calculated separately for each of the seven main types of conditions treated. This can be seen from Table V, cols. 2 and 3, the detailed results of all treatments being found in Table AIII at the end of the Report. These results are, of course, pertinent when considering the dose to individuals known to have received treatment to sites of the trunk and head. However the statistics of patients treated for non-malignant conditions which were available for Great Britain during the three month period in 1957 (II, Table 21) did not specify the sites treated. The mean marrow dose per treatment course is therefore given for all members of the sample survey irrespective of treatment site (Table V, cols. 4 and 5 and Table AIII). These values must be used (as here) when considering the dose to particular groups of patients for whom there are no data to distinguish the sites of treatment.

TABLE V

Radiotherapy of Non-Malignant Disease: National Survey 1957/58

Mean Marrow Dose in Rads per course of treatment

Treatment	Head and trunk* only		All cases	
	Male	Female	Male	Female
(1)	(2)	(3)	(4)	(5)
Skin Conditions				
Growths	4·8	7·6	2·3	3·3
Allergic and Inflammatory	10·4	7·9	3·5	3·2
Glandular Enlargements	5·5	5·9	5·5	5·9
Ankylosing Spondylitis	83·6	59·5	83·6	59·5
Arthritic and Rheumatic	27·1	22·0	18·9	15·1
Artificial Menopause	—	51·5	—	51·5

* Average of patients treated on head, trunk and heads of humerus and femur.

42. The average mean marrow dose delivered by X-ray treatment in the production of an artificial menopause is estimated to be 52 rads. In the survey of 1957 some centres reported the use of sealed radium sources for this purpose and, according to British Practice in Radiotherapy (11), this involved the application of 30–50 mg of radium for a period of 24–48 hours. Taking the mid-points of these values (40 mg and 36 hours) one arrives at a total of 1440 mghrs, for which the data of Holodny, Lechtman and Laughlin (11) give a mean marrow dose of 40 rads. The average dose is therefore not likely to be appreciably different from the 52 rads given by X-rays.

43. The annual number of patients treated with X-rays for non-malignant disease was estimated to be approximately 60,000 (II, 48). This is a small number compared with the total population and it is therefore inappropriate to convert the bone marrow dose involved into an annual dose per person in the whole population (as was done for diagnostic radiology, Para. 40). In place of it the product of the mean bone marrow dose per treatment course and the number of patients treated per year gives a measure of the total additional radiation exposure in terms of patient-rads. These figures are given in Table VI (and in more detail in Table A IV). They show totals of 617,000 patient-rads per year from treatments by X-ray and 95,000 patient-rads per year from treatments by radioactive isotopes (see Para. 38 and II Table 29). The largest contributions come, it will be noted, from the X-ray treatment of skin conditions (40·6%) and ankylosing spondylitis (25%) and from the induction of the artificial menopause (20·4%).

TABLE VI

Radiotherapy of Non-Malignant Disease: National Survey 1957/58

*Total Patient-Rads Exposure per year**

Treatment	Patient-rads per year (x10^3)	%
Skin conditions		
Growths	33·6	5·4
Allergic inflammatory ...	172·0	27·8
Ringworm	27·5	4·5
Others	17·7	2·9
Ankylosing Spondylitis	155·0	25·1
Arthritic and Rheumatic	33·6	5·5
Artificial Menopause	126·0	20·4
Other treatments	51·8	8·4
	617·	100·
Radioactive Isotope Treatments		
Iodine-131	45	
Phosphorus–32	50	
	95	

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* This total exposure in patient-rads is obtained by multiplying the mean *marrow* dose per treatment course with the number of patients treated per year.

(b) Treatment of malignant disease

44. The mean marrow doses received in the X-ray treatment of malignant disease are given for different sites in Table A V. These values have been calculated for X-rays of quality 2 mm Cu H.V.L. (II, Table 26).

45. The more extensive use today of supervoltage radiation in place of 200 kV radiation will not appreciably increase these doses since for both sources similar integral doses are received for square fields of irradiation 10–20 cm in size in the treatment of neoplasms 6–9 cm deep (13). For the treatment of neoplasms at greater depths the integral dose is increased with 200 kV radiation but this difference will be partially offset by the increase in total dose given at supervoltages.

46. The treatment of cancer of the thyroid with Iodine–131 gives rise to a bone marrow dose of the order of 1·7 rads per mCi administered whilst the use of Gold–198 is estimated to give 4 rads per mCi.

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(11) British Practice in Radiotherapy (Ed. Sir Ernest Rock Carling, B. W. Windeyer and D. W. Smithers) (London: Butterworth and Co.) 1955.

(12) Holodny, E., Lechtman, H., and Laughlin, J. S., 1961, Radiology, *77*, 1.

(13) Scarpa, G., 1960, Brit. J. Radiol., *33*, 770.

PART V. SUMMARY

General

47. In this Report the effects of radiation on the *individual* (somatic effects) have been considered and a dose relating to such effects has been determined on the basis of the data obtained in the 1957–58 national surveys (as given in the Second Report of the Committee published in 1960) together with extensive laboratory work (Paras. 2 and 3).

48. After considering the known somatic effects of radiation exposure, the Committee took the view that bone marrow is one of the tissues most susceptible to radiation damage and that leukaemia, a malignant form of bone marrow disease, is one of the important radiation effects to be considered. The Committee therefore adopted the criterion that the dose to the bone marrow was the relevant parameter to be measured and that the dose could best be expressed as the mean dose, averaged over the whole active marrow (Paras. 4, 5 and 6).

49. Because on average every member of the population undergoes an X-ray diagnostic examination every three to four years, the somatic dose from diagnostic radiology can be expressed as the mean marrow dose per person per year averaged over the whole population. These considerations do not apply to therapeutic procedures and the mean marrow doses relating to the treatment of non-malignant disease are therefore expressed as a total in patient-rads. In the case of the treatment of malignant disease, mean marrow doses per treatment course are given for typical radiotherapeutic procedures (Paras. 7, 8 and 9).

50. The results of the investigations show that the mean marrow dose contributed by diagnostic radiology was about 32 mrads per person per year. In addition, the annual radiation exposure from the treatment of non-malignant disease was 617,000 patient-rads from radiotherapy and 95,000 patient-rads from the use of radioisotopes (Paras. 10 and 11). The mean annual dose from diagnostic radiology is not such that there is any necessity for major restrictions in radiological practice. Emphasis is placed on the importance of following the recommendations in the Second Report so as to reduce the bone marrow dose. In particular the recommendations are stressed regarding the restriction of the size of the X-ray beam and the limitation of the X-ray examinations which involve irradiation of the foetus (Para. 12).

Determination of the mean bone marrow dose

51. The data available to calculate the mean bone marrow dose include (1) the national survey data given in the Committee's Second Report, (2) the measurement on a specially constructed model of the relationship between the dose at the skin surface of a patient and the absorbed dose in underlying bone marrow cavities for a large variety of radiation conditions, and (3) the published data on the distribution of the active bone marrow in the body (Paras. 13–25).

52. To facilitate the calculation of the bone marrow dose from different X-ray examinations and treatments the body was considered as an assembly of elements each 5 cm. long and 3 cm. across. For each such element the marrow dose was determined from (*a*) the known particular exposure conditions

of the patient, (*b*) the relevant measurements on the model and (*c*) the percentage of the total bone marrow present in the bones within the grid element concerned. The mean dose to the whole of the active marrow was thus derived (Para. 26).

The mean bone marrow dose in diagnostic radiology

53. The mean bone marrow dose per X-ray examination is given together with an analysis of the marked variations in the dose for essentially the same type of examination. On average, the mean marrow dose from a general diagnostic examination is 94 mrads. The doses for particular types of examination differ very considerably from this average, being for example as high as 600 to 1300 mrads for examinations of the gastro-intestinal tract and as little as 12 mrads for a single chest film. (Paras. 27-31 and Figs. 1 to 5).

54. From general diagnostic radiology the mean bone marrow dose per person of the population is estimated as 24·4 mrad. The more important examinations contributing to this figure are the barium meal (27%) and the barium swallow and barium enema (15%) (Paras. 32-33).

55. From mass miniature radiography of the chest, dental radiography and the diagnostic use of radioactive isotopes, the mean bone marrow doses per person of the population are estimated at 7·8, 0·1, and 0·1 mrads respectively The mean marrow dose for an individual mass miniature radiographic examination is 80 mrads. (Paras. 34-39).

56. The total annual population bone marrow dose from diagnostic radiology is therefore calculated to be 32·4 mrads per person. The mean marrow dose to an individual undergoing a diagnostic radiological procedure averages about 100 mrads for the years of the survey 1957/58; at the frequency of examinations then found (about 20 examinations) a total mean marrow dose of about 2 rads might be expected in a lifetime (Para. 40).

The mean bone marrow dose in radiotherapy

57. Estimates of the mean bone marrow dose per X-ray treatment course are given for the treatment of non-malignant conditions (Paras. 41-42). It is concluded that the annual radiation exposure from such treatments is 617,000 patient-rads and the mean marrow dose per treatment course averages about 10 rads. The individual dose naturally varies widely according to the type of the disease treated. A further 95,000 patient-rads is contributed by the use of Phosphorus–32 and Iodine–131 in the treatment of non-malignant diseases. (Para. 43).

58. Typical mean bone marrow doses received during the treatment of malignant disease are presented (Paras. 44–46).

CONCLUSIONS

59. Our surveys show that the diagnostic use of X-rays in 1957 produced on average a bone marrow dose of some 32 mrads per person of the population per year. The average individual examination resulted in a bone marrow dose of about 100 mrads and in a lifetime, the total marrow dose to an individual might average 2 rads.

60. The total bone marrow exposure from the use of X-rays to treat non-malignant conditions was 617,000 patient-rads or 10 rads on average per individual treated.

61. It is very difficult to interpret these doses in terms of estimates of risk of leukaemia either to the individual or to the population as a whole. The most recent appraisal by the United Nations Scientific Committee (2) of the available evidence on the relationship between leukaemia incidence and radiation dose shows that only by extremely speculative extrapolation can the present data be applied to the whole range of circumstances of irradiation for medical purposes. The reason is that the information on which such estimates can be based is limited almost entirely to the increase in the incidence of leukaemia following the irradiation of the bone marrow at the level of some hundreds of rads. The only information at lower doses is limited to the special case of the irradiation of the foetus in radiological examinations during pregnancy. Nevertheless, we think that such estimates of risk as can be made should be given, although they are speculative and are to be regarded with considerable reservations.

62. There is also some difficulty in expressing estimates of risk in a manner readily understandable and comparable with other risks of life. The present annual incidence of leukaemia in the United Kingdom amounts to about 50 to 60 cases per million of the population; expressed in another way, it can be said that the chance of an individual contracting leukaemia is between 50 and 60 in a million each year (although in fact this chance varies with age). It seems to us best, therefore, to express the risk from a given X-ray dose as a chance which is to be compared with this existing annual chance. Expressed in this way, an individual undergoing some 20 "average" X-ray examinations in the course of a lifetime, would have his annual chance of contracting leukaemia eventually raised (if at all) by at most 2 per million above the level of about 50 to 60 per million for a person having no X-ray examinations.

63. The bone marrow doses associated with the radiotherapy of non-malignant disease are on average considerably greater than those in radiological examinations. The average dose for one course of treatment would raise the annual leukaemia risk by 15 chances per million over a limited period of time.

64. It must be emphasized that the risk estimates we have made do not carry the certainty or the accuracy which numbers may suggest and that they are likely to be over-estimates rather than under-estimates. The most important consideration is that in diagnostic radiology they represent very small additions to the normal risks of contracting leukaemia, whereas the medical procedures themselves offer enormous advantages in the diagnosis and cure of disease.

65. These findings support the conclusions and recommendations given in our Second Report. They reveal no necessity for major restrictions in radiological work. The number and type of examinations must be dictated by the needs of the patient. The implementation of the recommendations of our Second Report will materially reduce the dose to the bone marrow as well as to the gonads. In particular, we would stress the recommendations regarding the restriction of the size of the X-ray beam to the minimum required for the examination and the limitation of all X-ray examinations which involve the irradiation of the foetus.

66. Any major change in the techniques used in medical radiology which might radically alter the radiation levels to the gonads or bone marrow should be carefully reviewed.

Signed:

Adrian (Chairman)
L. G. Blair
J. C. McC. Browne
Ronald J. G. Grewcock
Austin Bradford Hill
Robert J. Kellar
Peter Kerley
D. R. Maitland
W. V. Mayneord
C. Naunton Morgan
Kenneth Robson
T. Holmes Sellors
Gordon R. Seward
F. W. Spiers
Edward Wayne
Charles Wells
Brian Windeyer

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APPENDIX A

TABLE A I

General Diagnostic Radiology: National Survey 1957/58
Numbers of Observations and Mean Marrow Dose per Examination

Type of Examination	MALE				FEMALE				
	Children		Adults		Children		Adults		
	No.	Dose mrad	No.	Dose mrad	No.	Dose mrad	No.	Dose mrad	Skin dose rad
Head	28	43·2	71	32·0	23	35·9	68	38·8	1·4
Cervical Spine	1	109	24	53·6	2	28·8	65	48·7	0·6
Dental (Hosp.)	—	—	5	30·5	2	30·5	4	30·5	1·6
Barium Swallow	—	—	2	1295	4	154	10	586	R 1·4 F^{x} 6·4
Arm and Hand	—	—	—	—	—	—	—	—	1·7
Clavicle Shoulder	1	6·8	12	38·4	4	34·5	19	81	0·9
Dorsal Spine	3	54·2	33	199	5	142	41	218	2·0
Whole Chest	77	35·9	503	12·1	81	14·3	470	13	R 0·15 F^{x} 2·0
Thorax Ribs and Sternum	1	64·9	34	176	3	44·5	26	36·5	0·5—1·3
Barium Meal	10	485	206	505	4	627	157	799	R 1·7 F^{+} 4·4
Cholecystography	—	—	40	147	—	(149)	99	149	1·5
Abdomen	33	96·3	171	123	44	90	187	129	1·4
Abdomen (Obstetric)	—	500^{+}	—	—	—	500^{+}	127	206	3·8
Intravenous Pyclogram	28	470	321	584	34	265	247	452	1·7
Retrograde Pylogram	1	93·8	15	443	1	312	17	330	1·4
Salpinography	—	—	—	—	—	—	26	213	R 1·2 F^{x} 3·4
Placentography	—	—	—	—	—	—	—	—	3·0
Pelvimetry	—	1120^{+}	—	—	—	1120^{+}	110	283	10·3
Cystography	2	350	6	171	2	92·1	8	944	3·1
Barium Enema	2	866	33	528	1	878	35	1062	R 1·5 F^{x} 4·9
Pelvis	25	43·3	152	130	20	61·4	166	142	2·1
Lumbar Spine	15	396	314	270	15	428	302	270	4·5
Lumbo Sacral Joint	6	182	45	291	3	317	64	217	5·8
Hip and Femur (upper third)	60	35·2	74	57·3	36	44·5	106	59·7	1·4
Rest of Femur	—	—	—	—	—	—	—	—	0·4
Leg and Foot	—	—	—	—	—	—	—	—	0·3
Angiography (head)	—	—	1	128	—	—	—	—	1·0
Angiography (abdomen)	—	—	—	—	—	—	3	379	3·3
Tomography Chest	—	—	14	359	—	392	9	392	0·8
Cardiac Catheterization	—	—	—	—	3	43·1	1	191	1·3
Broncbogram	—	31·3	4	31·4	—	31·4	—	31·4	0·2

$^{+}$ Foetal dose ^{x} r/min
R Radiography   F Fluoroscopy

TABLE A II

General Diagnostic Radiology: National Survey 1957/58

Annual Mean Marrow Dose in Millirads per Person

Examination Type	CONTRIBUTION									
	MALE				FEMALE				Total	%
	Children		Adults		Children		Adults			
	No. exams per 1000 per year	Mean marrow dose per person per year	No. exams per 1000 per year	Mean marrow dose per person per year	No. exams per 1000 per year	Mean marrow dose per person per year	No. exams per 1000 per year	Mean marrow dose per person per year		
Head	1·71	0·074	6·30	0·201	1·21	0·044	5·49	0·214	0·533	2·37
Cervical Spine	0·50	0·055	1·86	0·100	0·35	0·010	1·62	0·079	0·244	1·09
Dental (Hosp.)	0·31	0·010	1·11	0·034	0·43	0·013	1·42	0·044	0·101	0·45
Barium Swallow	0·01	0·013	0·57	0·739	0·07	0·011	0·75	0·439	1·202	5·35
Arm and Hand	3·35	—	11·07	—	2·53	—	8·21	—	—	—
Clavicle Shoulder	0·35	0·002	2·47	0·095	0·23	0·009	1·78	0·144	0·250	1·11
Dorsal Spine	0·07	0·004	1·24	0·246	0·15	0·022	1·47	0·320	0·592	2·63
Whole Chest	9·22	0·332	56·17	0·678	7·98	0·113	54·67	0·714	1·837	8·17
Thorax Ribs and Sternum ...	0·14	0·009	1·81	0·320	0·13	0·006	1·12	0·040	0·375	1·67
Barium Meal	0·04	0·020	4·70	2·374	0·05	0·032	4·44	3·548	5·974	26·56
Cholecystography	—	—	1·30	0·192	0·01	0·001	2·17	0·325	0·518	2·30
Abdomen	0·49	0·048	2·65	0·327	0·43	0·039	2·75	0·356	0·770	3·42
Abdomen (Obstetric)	0·8†	0·400†	—	—	0·8†	0·400†	1·60	0·329	1·129	5·02
Intravenous Pyelogram ...	0·14	0·066	2·24	1·309	0·13	0·034	1·95	0·881	2·290	10·19
Retrograde Pyelogram ...	0·01	0·001	0·32	0·142	0·01	0·004	0·39	0·129	0·276	1·23
Salpinography	—	—	—	—	—	—	0·20	0·043	0·043	0·19
Pelvimetry	0·19†	0·210†	—	—	0·19†	0·210†	0·37	0·105	0·525	2·34
Cystography	0·01	0·004	0·10	0·017	0·01	0·001	0·07	0·066	0·088	0·39
Barium Enema	0·01	0·009	1·06	0·560	0·32	0·028	1·47	1·562	2·159	9·60
Pelvis	0·28	0·011	1·56	0·203	0·11	0·007	0·35	0·050	0·271	1·21
Lumbar Spine	0·13	0·052	3·51	0·947	0·08	0·034	1·60	0·432	1·465	6·52
Lumbo Sacral Joint	0·06	0·011	2·18	0·634	0·02	0·006	0·34	0·074	0·725	3·22
Hip and Femur (upper third)	0·42	0·015	1·60	0·092	0·42	0·018	2·57	0·154	0·279	1·24
Rest of Femur	0·24	—	1·55	—	0·14	—	0·96	—	—	—
Leg and Foot	2·18	—	10·74	—	1·56	—	7·21	—	—	—
Angiography (head)	—	—	0·23	0·029	0·01	0·001	0·14	0·018	0·048	0·21
Angiography (abdomen) ...	—	—	0·07	0·027	—	—	0·01	0·004	0·031	0·14
Tomography Chest	0·01	0·004	1·19	0·427	0·02	0·007	0·75	0·294	0·732	3·26
Cardiac Catheterization ...	0·01	n	0·002	n	0·01	n	0·03	0·006	0·006	0·03
Bronchogram	0·02	0·001	0·35	0·011	0·04	0·001	0·24	0·007	0·020	0·09
Total	—	1·351	—	9·704	—	1·051	—	10·377	22·483	100·

† Foetal dose. n<0·001.

TABLE A III

Radiotherapy of Non-malignant Disease:

National Survey 1957/58

Mean Marrow Dose per Treatment Course

Condition treated	Head and Trunk only								All cases							
	Children				Adults				Children				Adults			
	Males		Females		Males		Females		Males		Females		Males		Females	
	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad	No.	Mean Dose rad
1. Skin Conditions																
Growths	27	14·6	21	10·0	52	4·8	80	7·6	91	4·3	125	1·7	110	2·3	185	3·3
Allergic and Inflammatory	10	10·8	13	23·3	201	10·4	230	7·9	26	4·2	18	16·8	600	3·5	578	3·2
Ringworm	5	92·0	1	62·5	2	36·0	—	—	6	76·0	2	31·3	4	18·0	3	18·0†
Others	1	49·0	1	5·6	38	6·9	38	4·3	1	49·0	1	5·6	65	4·0	115	1·4
2. Glandular Enlargements	—	—	2	6·2	7	5·5	1	5·9	—	—	2	6·2	7	5·5	1	5·9
3. Ankylosing Spondylitis	—	—	—	—	70	83·6	14	59·5	—	—	—	—	70	83·6	14	59·5
4. Arthritic and Rheumatic	—	—	—	—	23	27·1	29	22·0	—	—	—	—	33	18·9	42	15·1
5. Artificial Menopause	—	—	—	—	—	—	74	51·5	—	—	—	—	—	—	74	51·5
6. Deafness	5	9·4	2	8·6	7	3·5	10	3·7	5	9·4	2	8·6	7	3·5	10	3·7
7. Other non-malignant	1	2·6	2	282·0	15	20·9	35	27·6	1	2·6	2	282·0	23	13·6	37	26·2

† Assumed male value in absence of data.

Footnote: The computer programme (para 26) was adapted to make an approximate estimate of the bone marrow dose from small treatment areas which receive high doses.

TABLE A.IV

Radiotherapy of Non-Malignant Disease:

National Survey 1957/58

*Total Patient-rads Exposure per year**

X-ray treatments	Patient rads per year (x10³)					
	CONTRIBUTION					
	Male		Female		Total	%
	Children	Adults	Children	Adults		
1. Skin Conditions						
(*a*) Growths, etc. ...	9·8	5·5	6·1	12·2	33·6	5·4
(*b*) Allergic and inflammatory etc.	4·3	72·6	14·6	80·5	172·	27·8
(*c*) Ringworm ...	20·8	1·8	1·2	3·7	27·5	4·5
(*d*) Others	4·3	8·5	1·2	3·7	17·7	2·9
2. Glandular Enlargements etc.	n	n	n	n	n	n
3. Ankylosing Spondylitis	—	133·	—	22·	155·	25·1
4. Arthritic and Rheumatic, etc.	n	16·5	n	17·1	33·6	5·5
5. Artificial Menopause ...	—	—	—	126	126	20·4
6. Deafness	2·4	n	1·8	n	4·2	0·7
7. Any other non-malignant conditions	n	9·8	12·8	25·	47·6	7·7
					617·2	100·

n less than 1 x 10³ patient-rad.

* This total exposure in patient-rads per year is obtained by multiplying the mean marrow dose per treatment course with the number of patients treated per year.

TABLE A V

Radiatherapy of Malignant Conditions

Mean Marraw Dose per treatment caurse

Malignant Conditions	*Marrow dose rads*
Buccal Cavity and Pharynx	114
Oesophagus	320
Stomach	157
Small Intestine	77
Large Intestine	70
Rectum	31
Other Digestive	106
Nose, etc.	47
Larynx	40
Trachea, etc.	399
Other respiratory	392
Breast male	10
female	19
Cervix*	Radium 260 X-rays 208 } 468
Other Uterus	276
Ovary	198
Prostate	94
Testis	476
Kidney	79
Bladder	223
Eye	13
Brain	109
Thyroid	62

---

* For the treatment of the cervix uteri a standard Manchester technique irradiation (14) of 9100 mghrs has been assumed in addition to two supplementary fields to the parametrium. The marrow dose from the radium treatment was deduced from Holodny et al. (12).

(12) Holodny, E., Letchman, H., and Laughlin, J. S., 1961. Radiology, *77*, 1.

(14) Todd, M., and Meredith, W. J., 1952, Brit. J, Radiol, *26*, 252.

APPENDIX B

Histograms showing variation in bone marrow dose and its correlation with other parameters

Figs. 1-2 refer to male examinations and Figs. 3-4 to female examinations. All the histograms in Figs. 1-4 are plotted with the mean bone marrow dose for each examination along the horizontal axis. Each vertical column of histograms refers to one examination type and these show in vertically descending order (i) the frequency of the occurrence of a particular mean marrow dose for that particular examination in the survey (the white triangle indicates the mean value taken from Table A1); (ii) the variation in the total skin dose in roentgens delivered during each examination plotted against the mean marrow dose; (iii) the Half Value layer in mm Aluminium for each bone marrow dose value; (iv) the total field area irradiated per examination plotted against the resultant mean marrow dose; and (v) the total fluoroscopic exposure time per examination plotted against the mean marrow dose. The reasons for particularly high mean marrow doses in any one examination may be ascertained by considering the five histograms together. Fig. 5 shows the variations in the foetal marrow dose observed during the survey for examinations of the obstetric abdomen and pelvimetry.

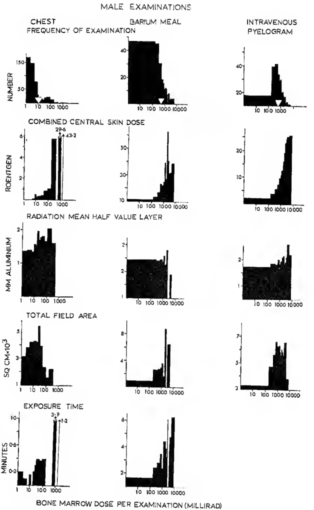
MALE EXAMINATIONS
CHEST
BARIUM MEAL
INTRAVENOUS PYELOGRAM
FREQUENCY OF EXAMINATION
NUMBER
150
50
40
20
40
20
1 10 100 1000
10 100 1000 10000
10 100 1000
COMBINED CENTRAL SKIN DOSE
ROENTGEN
29·6
43·2
6
4
2
50
30
10
20
10
1 10 100 1000
10 100 1000 10000
10 100 1000 10000
RADIATION MEAN HALF VALUE LAYER
MM ALUMINIUM
2
1
3
2
1
2
1
1 10 100 1000
10 100 1000 10000
10 100 1000 10000
TOTAL FIELD AREA
SQ CM×10^3
5
3
1
8
4
7
5
3
1 10 100 1000
10 100 1000 10000
10 100 1000 10000
EXPOSURE TIME
MINUTES
3·9
1·2
1·0
0·6
0·2
6
4
2
1 10 100 1000
10 100 1000 10000
BONE MARROW DOSE PER EXAMINATION (MILLIRAD)

FIG. 1.

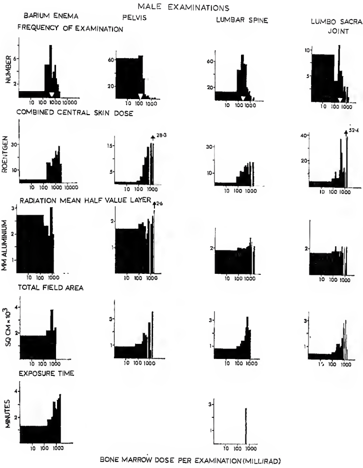
MALE EXAMINATIONS
BARIUM ENEMA
PELVIS
LUMBAR SPINE
LUMBO SACRAL JOINT
FREQUENCY OF EXAMINATION
NUMBER
COMBINED CENTRAL SKIN DOSE
ROENTGEN
28·3
52·4
RADIATION MEAN HALF VALUE LAYER
2·6
MM ALUMINIUM
TOTAL FIELD AREA
SQ CM × 10^3
EXPOSURE TIME
MINUTES
10 100 1000 10000
BONE MARROW DOSE PER EXAMINATION (MILLIRAD)

Fig. 2.

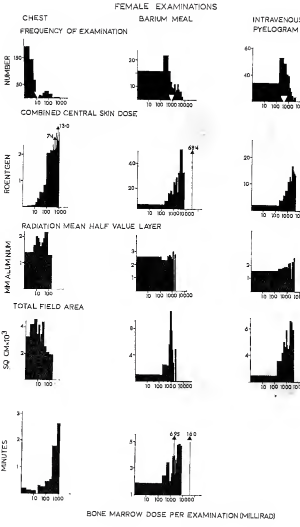
FEMALE EXAMINATIONS
CHEST
BARIUM MEAL
INTRAVENOUS PYELOGRAM
FREQUENCY OF EXAMINATION
NUMBER
150
50
30
10
60
40
10 100 1000
10 100 1000 10000
COMBINED CENTRAL SKIN DOSE
ROENTGEN
13·0
7·4
2
1
68·4
40
20
10
RADIATION MEAN HALF VALUE LAYER
MM ALUMINIUM
3
TOTAL FIELD AREA
SQ CM×10³
4
8
6
MINUTES
6·95
16·0
5
BONE MARROW DOSE PER EXAMINATION (MILLIRAD)

Fig. 3.

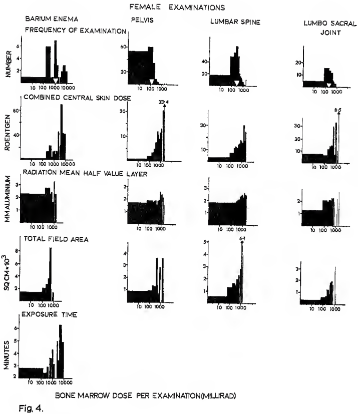
FEMALE EXAMINATIONS
BARIUM ENEMA
PELVIS
LUMBAR SPINE
LUMBO SACRAL JOINT
FREQUENCY OF EXAMINATION
NUMBER
COMBINED CENTRAL SKIN DOSE
ROENTGEN
33·4
8·5
RADIATION MEAN HALF VALUE LAYER
MM ALUMINIUM
TOTAL FIELD AREA
SQ CM × 10³
6·1
EXPOSURE TIME
MINUTES
10 100 1000 10000
BONE MARROW DOSE PER EXAMINATION(MILLIRAD)

Fig. 4.

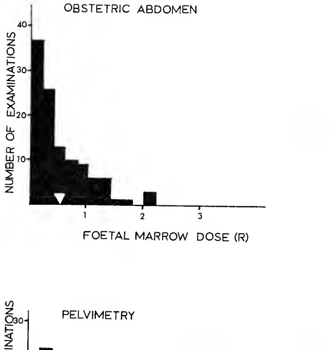
OBSTETRIC ABDOMEN
NUMBER OF EXAMINATIONS
40
30
20
10
1
2
3
FOETAL MARROW DOSE (R)
PELVIMETRY
NUMBER OF EXAMINATIONS
30
20
10
1
2
3
4
5
FOETAL MARROW DOSE (R)

Fig. 5.

APPENDIX C

RECOMMENDATIONS IN SECOND REPORT

I. GENERAL

(*a*) There should be clear-cut clinical indications before any X-ray examination is undertaken, and it should be ascertained whether there has been any previous radiological examination which would make further examination unnecessary. For this purpose the case sheet should have a section labelled "previous X-rays".

(*b*) To reduce unnecessary examinations, arrangements should be made for the ready availability of previous films and for the routine transfer of films from one hospital to another.

(*c*) All requests for examinations should state precisely the clinical indications and the information required.

(*d*) There should be consultation between clinician and radiologist before extensive or repeated radiological examinations of young individuals are undertaken. It must be realised that radiological exposure is just as much the responsibility of the clinician as of the radiologist.

(*e*) To reduce the necessity for repeat investigation strict attention should be paid to adequate preparation of the patient before abdominal investigation.

(*f*) Special precautions should be adopted in the radiography of pregnant women. Only essential examinations should be carried out during pregnancy and particular care should be taken to avoid irradiation of the foetus whenever possible. In all women of child-bearing age the clinician requesting the examination should never overlook the possibility of early pregnancy.

(*g*) Any previous history of radiotherapy should be ascertained before a new course of treatment is undertaken. Permanent records of all radiotherapy should be maintained and be readily available for transfer from one hospital to another.

(*h*) Consideration should always be given to alternative methods of treatment before radiotherapy for non-malignant conditions is undertaken.

II. TECHNIQUES

In every radiological examination, care should be taken to reduce to a minimum the irradiation of the gonads. The steps necessary to this end are discussed throughout the Report. In particular, strict attention should be paid to the following:—

1. General to all forms of radiology

(*a*) *Limitation of field size*

Strict limitation of field size to the area necessary for the particular examination or treatment should be routinely practised. In diagnostic radiology, this should be done by fitting light beam diaphragms rather than circular cones, particularly when a large field size is used.

(*b*) *Beam direction*

Whenever possible, the beam should not be directed towards the gonads and this should be borne in mind particularly in examinations or treatments of the limbs, especially of the hands with the patient in the sitting position.

(*c*) *Gonad shields*

Adequate gonad shields should invariably be used in examinations or treatments which are likely to give a high gonad dose, unless they interfere with the proposed examination or treatment.

(*d*) *Immobilizing devices*

In the examination or treatment of children or patients who need support, mechanical devices to ensure immobilization should be used.

2. **Particular to radiography**

(*a*) *High speed films and screens*

The use of the fastest films and screens consistent with satisfactory diagnostic value is strongly recommended.

(*b*) *Automatic timing devices*

Repeat exposures should be kept to a minimum by the use of photo-electric timers or similar devices. Where these are not practicable, accurately pre-set timing devices should be readily available.

3. **Particular to fluoroscopy**

(*a*) *Limitation of use*

Fluoroscopy should not be undertaken if the same information can be obtained by radiography. It should not be used for locating metallic foreign bodies at operations as electronic metal-locating equipment is now available.

(*b*) *Dark adaptation*

No fluoroscopic examination should be undertaken without adequate dark adaptation on the part of the clinician undertaking the examination (at least 10 minutes).

(*c*) *Automatic switches*

All fluoroscopy machines should be fitted with a clock, or other timing device, which automatically cuts off the beam after a certain time or a certain dose.

(*d*) *Image intensification*

More general use should be made of image intensification in such examinations as cardiac catheterisation. There is urgent need for more research into the problems of image intensification for medical purposes.

4. **Particular to mass miniature radiography**

In accordance with the recommendations of our Interim Report, chest examinations of pregnant women should not be carried out with mass miniature techniques, but by full size films with strict limitation of field size. For the chest radiography of children and adults of short stature either technique may be used, so long as adequate steps can be taken to exclude the gonads from the X-ray beam; otherwise large films should be used.

5. **Particular to radiotherapy**

(*a*) In the treatment of skin conditions, use should always be made of the softest quality of radiation consistent with adequate irradiation of the tissues to be treated.

(*b*) Radiation should not be applied to the ovaries for the production of a temporary artificial menopause, or for the treatment of infertility.

III. EQUIPMENT

1. Checks should be made regularly to ensure that all radiological equipment is maintained to the standard laid down in the Code of Practice for the Protection of Persons Exposed to Ionizing Radiations. Obsolete and erratic equipment should be replaced immediately.
2. The development of automatic devices, and particularly those which reduce the risks of human error, should be actively encouraged.

IV. STAFF AND TRAINING

1. Attention should be given to the provision at all times of adequate medical and technical staff in radiological departments.
2. In sparsely populated areas where radiologists or radiographers are not available, training in the safe use of equipment should be given to the general practitioners or nurses who have to carry out any minor X-ray examinations.
3. Adequate instruction should be given in the medical and dental under-graduate curricula on the uses and hazards of ionizing radiations.

V. SURVEILLANCE

The genetic dose to the population from diagnostic and therapeutic radiology should be kept under effective review by the Health Departments.

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MINISTRY OF HEALTH
SCOTTISH HOME AND HEALTH DEPARTMENT

RADIOLOGICAL HAZARDS TO PATIENTS

Final Report of the Committee

LONDON
HER MAJESTY'S STATIONERY OFFICE
1966

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††J. M. Foster

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* Appointed April 1964.
† Appointed March 1965.
†† Up to March 1965.

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